INSECURE PROPERTY AND THE EFFICIENCY OF EXCHANGE*

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We examine the effect of insecure property and its accompanying enforcement costs on the efficiency of exchange. Because of the large enforcement costs that may be induced by the expectation of exchange, limited settlement without exchange may be *ex ante* superior for an adversary or even Pareto dominant. We therefore show how the removal of restrictions on exchange and the development of secure property are related.

For much of history and in many places in the world today, property over economic resources has been or still is insecure. To enforce their claims on such resources, interested parties typically have to engage in litigation, monitoring or even arming and pay the enforcement costs that accompany such actions. The size of these costs can be expected to depend, among other factors, on the stakes involved. But for the same insecure and contested resource the stakes can be different depending on whether the resource is transferable or exchangeable once captured. What does the presence of enforcement costs imply for the *ex ante* efficiency of different forms of settlement? Is *ex post* efficient exchange always *ex ante* Pareto optimal?

In this paper we address these and related questions. We show that *ex ante* – ie, with the costs of enforcement endogenously determined – having *ex post* efficient exchange may be Pareto inferior or preferred only by one party. Thus, in the presence of insecure property, a more limited form of settlement – eg, one according to which only the contested resource is negotiated and divided – can be more efficient. This outcome occurs because the expectation of full tradeability under exchange raises the stakes by rendering not just the contested resource negotiable, but also the disposition of other commodities which, though not directly contested, may nonetheless be traded down the road. This enlarges the bargaining set and induces adversaries to intensify their efforts to better their bargaining positions, thereby generating higher enforcement costs that may overwhelm the traditional (*ex post*) gains from trade under secure property. Only when the gains from trade are large enough can unlimited exchange be *ex ante* efficient.

To illustrate these ideas we employ a model which has as its limiting case a simple neoclassical model of exchange with completely secure property. The gains from trade in the model, and therefore the degree to which unlimited

exchange is efficient, depend on the dissimilarity of the agents' initial factor endowments.

Our main finding suggests a correlation between the security of property rights and the efficiency or stability of exchange. This correlation helps us understand two closely related first-order facts, amply documented in the economic history literature: First, the removal of restrictions on exchange and the development of markets have gone hand-in-hand with the development of secure property rights (see, eg, Cameron (1993) pp. 211–4). The country which for centuries was removing internal trade impediments the most, Britain, was also developing the most secure property rights. And, more recently, the removal of restrictions on exchange in many developing and transition economies has been typically accompanied by a revamping of the legal system and making property more secure (or, at least, this is what countries are advised to do). The second related fact is the presence of numerous restrictions on exchange in traditional economies that also happened to have, or still have, insecure property rights. North (1990, p. 33) has emphasised how enforcement costs can foreclose complex exchange and limit the possibilities for economic growth, and how exchange has, in fact, been severely hampered by such costs in history.

The model we employ has formal similarities with the literatures on rent-seeking contests and conflict.[1] Two features differentiate our approach: first, we distinguish between winner-take-all conflict outcomes and negotiated settlements with and without further exchange in commodities; and second, we compare the efficiency properties of limited settlement and exchange under the threat of conflict. For the literature on rent-seeking contests we clarify how the usuage of real resources, a central concern of this literature, is conditioned by the regime one considers.[2] With regard to the literature on conflict, we, too, are concerned with arming and conflict over the capture of economic resources.[3] We go beyond these points, though, in that we study the properties of settlements that occur in the shadow of conflict. Moreover, since the potential for conflict exists here because of the presence of an insecure resource, the environment within which agents interact in this paper is closer to that found in many economies where there is room for appropriation, without conflict necessarily becoming completely generalised.

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[1] The problem and the costs we examine are distinct from those of the overexploitation of open access resources. Starting with Gordon (1954), the literature on open-access resources is large. The comparative examination of different forms of property has largely contrasted private property to an open access regime (Furubotn and Pejovich, 1972). de Meza and Gould (1992), however, have allowed for the costly enclosure of the commons and show that such costly enclosure may be inefficient.

[2] Beginning with the formal work of Tullock (1980), the related literature includes Nitzan (1991); Konrad and Schlesinger (1997), and many others.

[3] This literature includes papers on conflict among nations (Brito and Intriligator, 1985; Garfinkel, 1990; Eaton and Gersovitz, 1984), conflict between social classes (Grossman, 1991), conflict in general (Neary, 1997), legal conflicts (Gould, 1973), contests within organisations (Rajan and Zingales, 2000), interactions in the absence of property rights (Hirshleifer, 1995) and trade in insecure commodities (Anderson and Marcoullier, 1997; Anderton et al., 1999).

1. The Basic Framework

Two agents, labelled 1 and 2, compete for claims to a resource which for specificity we will refer to as 'land'. Denote by T the aggregate supply of land. Each agent i possesses T_i ($\equiv t_i T$) secure units and the remaining T_0 ($\equiv t_0 T$) units are insecure in the sense that property rights over them are difficult or costly to enforce. Every agent i also possesses R_i units of a private and inalienable resource, which we will call 'labour'. Agent i may allocate G_i units of his labour to the production of 'guns'. The remaining labour units can be used by the agent to produce one-to-one an intermediate input which we denote by $L_i (\equiv R_i - G_i)$.

Agent i's welfare depends on his productive input L_i as well as the amount of land he (or she) will control. Temporarily dropping subscripts, for every T and L that agent i controls, his well-being is determined by a neoclassical function $F(T, L)$ with the following properties:

$F(T, L)$ is twice differentiable, increasing, strictly concave, and linearly homogeneous.

(C1)

We can interpret $F(T, L)$ either as a production function or as a utility function with the arguments being consumption goods. For example, land could be thought of as producing one-to-one 'oil' and labour could be thought of as being used, also one-to-one, in the production of 'butter', with oil and butter being final goods.[4] Henceforth we adopt the production interpretation but the reader should keep in mind that the utility interpretation fits our formal analysis equally well.

For a given pair of guns (G_1, G_2), we denote with $p(G_1, G_2)$ and with $1 - p(G_1, G_2)$ the winning probabilities of agents 1 and 2, respectively. Formally, we assume

$p(G_1, G_2) \in [0, 1]; \quad p(G_1, G_2) = 1 - p(G_2, G_1); \quad p(\cdot, \cdot) \text{ is twice differentiable};$

$p_{G_1} \equiv \partial p / \partial G_1 > 0, \quad p_{G_2} \equiv \partial p / \partial G_2 < 0;$ (C2)

$p_{G_1 G_1} \equiv \partial^2 p / \partial G_1^2 \le 0, \quad p_{G_2 G_2} \equiv \partial^2 p / \partial G_2^2 \ge 0.$

Condition (C2) requires that the two agents have equal winning probabilities when they possess equal quantities of guns. Naturally, the larger the quantity of guns an agent possesses the larger is his winning probability and, consequently, the lower is the winning probability of his opponent. Lastly, an agent's winning probability is assumed to be concave in his or her guns.

When conflict is the only way to acquire the disputed land T_0 and the winner of the contest receives all of it, the agents' payoff functions are defined as:[5]

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[4] In Skaperdas and Syropoulos (2001) we follow such an interpretation with Cobb-Douglas preferences and under the simplifying assumption of the agents (interpreted as 'countries') being 'small' and therefore price-takers.

[5] Our use of the term 'guns' should be viewed more broadly as our framework applies to contexts in which conflict is not literally armed as, for example, in legal conflicts (Gould, 1973; Hirshleifer and Osborne, 1999). In such applications, the Gs would be interpreted as litigation expenditures.

$$U^1(G_1, G_2) = p(G_1, G_2)F(T_1 + T_0, R_1 - G_1) + [1 - p(G_1, G_2)]F(T_1, R_1 - G_1) \quad (1a)$$

$$U^2(G_1, G_2) = [1 - p(G_1, G_2)]F(T_2 + T_0, R_2 - G_2) + p(G_1, G_2)F(T_2, R_2 - G_2). \quad (1b)$$

In legal battles adversaries often avoid overt conflict through negotiated, out-of-court settlements, typically after having incurred litigation costs. Likewise, in our framework, if *for any prior and irrevocable choice of guns* the agents are able to (i) communicate with one another, and (ii) physically divide the contested resource, it will be in their mutual interest to do so and avoid conflict. To establish this property consider the following protocol of actions. First, each agent i allocates a portion of his primary resource R_i into the production of guns. Second, settlement occurs only if every agent can obtain a higher payoff under it, as compared to the payoff described in (1).

To compare settlement to winner-take-all conflict, recall that $F(T, L)$ is by (C1) strictly concave in T, that $p \equiv p(G_1, G_2)$, and $L_i \equiv R_i - G_i$ $(i = 1, 2)$. Together, these properties imply

$$F(T_1 + pT_0, L_1) = F[p(T_1 + T_0) + (1 - p)T_1, L_1] > pF(T_1 + T_0, L_1)$$
$$+ (1 - p)F(T_1, L_1) \quad (2a)$$

for agent 1, and

$$F[T_2 + (1 - p)T_0, L_2] = F((1 - p)(T_2 + T_0) + pT_2, L_2) > (1 - p)F(T_2 + T_0, L_2)$$
$$+ pF(T_2, L_2)$$

$$(2b)$$

for agent 2. Note that the right-hand side of the above inequalities coincides with the payoff each agent would receive under conflict. Together, inequalities (2a) and (2b) show that division of the contested land T_0 according to the winning probabilities p and $1 - p$ for for players 1 and 2, respectively, Pareto-dominates conflict. Of course, partitioning T_0 on the basis of p is just one such rule and there exist other divisions that yield payoffs superior to the ones under conflict. The important point is that, *given guns, both agents will have an incentive to settle their differences.*

But this settlement story does not have to end here. Land is complementary to labour in production and, upon the division of T_0, the agents may be able to engage in ordinary exchange of factor services and output which, again, given guns, should be Pareto-improving. To see this, consider the left-hand-sides of (2a) and (2b) which reveal that, after dividing the contested land T_0 according to p, agents 1 and 2 will respectively control the factor pairs $(T_1 + pT_0, L_1)$ and $(T_2 + (1 - p)T_0, L_2)$. But this allocation is inconsistent with the conditions for Pareto optimality because the marginal rates of technical substitution between land and labour generally differ across the agents. Thus, depending on the agents' initial factor endowments, further payoff improvements could be achieved if an agent exchanged, say, a portion of his labour or land services for the other agent's services of land, labour, or just the final good.
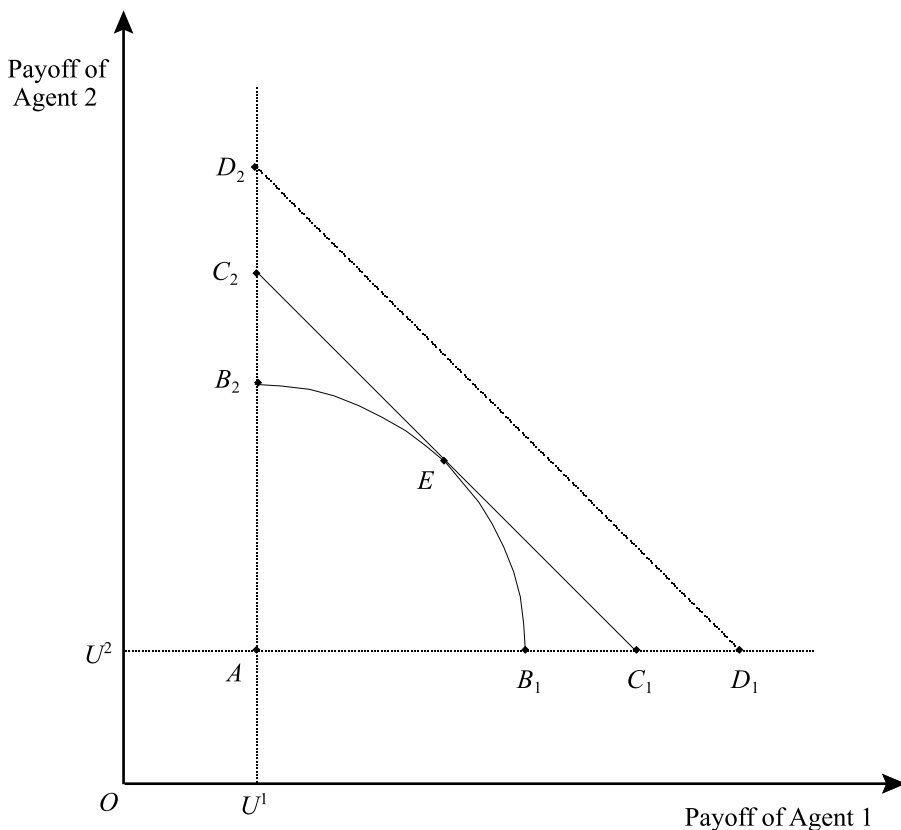
Fig. 1. *Payoff Possibilities*

The ideas just described can be illustrated with the help of Fig. 1 which depicts the agents' payoff opportunities under the possibilities discussed for *an exogenously given choice of guns* (G_1, G_2). Point A represents the payoffs under conflict. Curve $B_1 B_2$ is the payoff frontier that would arise if the agents could divide and share the contested land T_0. Curve $C_1 C_2$ is the payoff frontier that would arise if, after settling their claims to land, the agents could engage in further exchange. Point E corresponds to an allocation of resources that ensures identical marginal rates of substitution in production and thus no additional benefits from exchange.[6] Curve $D_1 D_2$ represents the unconstrained Pareto payoff frontier – ie, the one that would arise in a state of 'Nirvana' in which no guns are produced, land is divided peacefully, and efficient exchange takes place. In other words, $D_1 D_2$ is the familiar Pareto frontier of neoclassical theory under completely secure property. In a well-defined sense, then, the neoclassical structure is a limiting and, consequently, special counterpart of the model considered here.

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[6] The $C_1 C_2$ frontier in Fig. 1 is linear because $F(\cdot, \cdot)$ is by assumption linearly homogeneous.

2. Limited Settlement Versus Exchange: Why Exchange is not Always Ex Ante Efficient

To determine the quantity of guns the two agents will produce prior to negotiation and settlement we need to specify their payoff functions under each contingency. We will now first specify appropriate payoff functions and then compare the individual and social outcomes under the following two regimes: (i) When agents *ex ante* expect to bargain over the division contested land without engaging in additional exchange; (ii) when agents bargain to divide land knowing that it will be accompanied by *ex post* efficient exchange. For brevity, we christen these regimes 'Limited Settlement' and 'Exchange', respectively.[7]

2.1. *Payoffs under Limited Settlement and Exchange*

Outcomes under Limited Settlement and Exchange ultimately depend on the fallback positions the two sides would revert to in the event of disagreement. In our case, the fallback positions, usually called disagreement points in bargaining theory, are identified with the conflict payoffs described in (1). Different choices of guns induce different disagreement points and different payoff opportunities for the two agents. As with the incomplete-contract approach to the theory of the firm (see, for example, Grossman and Hart (1986); Chiu (1998) and de Meza and Lockwood (1998)) in which relationship-specific investments are non-contractible, we too assume here that agents cannot sign binding contracts on their production and potential use of guns. Accordingly, the agents' gun decisions are non-cooperative. Further, these decisions are irreversible and occur prior to the agents' negotiations regarding the division of factor inputs (or of output). Consequently, the actual quantities of guns produced depend on their expectations about the regime that will prevail down the road.

   To isolate the importance of regimes with regards to incentives, we suppose the agents' payoffs under Limited Settlement and Exchange are determined under the Nash bargaining solution, the path followed by much of the literature on incomplete contracts. In our context, this solution is also approximated by an alternating offers model in which there is a risk of breakdown of the bargaining process (see Binmore *et al.* (1986)).[8]

   Let $\gamma \in [0, 1]$ denote the share of the contested land (T_0) agent 1 receives under Limited Settlement. Since $1 - \gamma$ represents agent 2's share, the agents' payoff functions under this regime can be written as

$$V^1(\gamma, G_1) = F(T_1 + \gamma T_0, R_1 - G_1) \tag{3a}$$

$$V^2(\gamma, G_2) = F[T_2 + (1 - \gamma)T_0, R_2 - G_2]. \tag{3b}$$

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[7] For brevity, space limitations, and to also place settlement under the threat of conflict at centre stage, we exclude pure conflict from our comparison here. For circumstances under which conflict is preferred to cooperation in related environments see Skaperdas and Syropoulos (1996*a,b*).

[8] In a framework similar to the one examined in this paper, Anbarci *et al.* (2001) show how different bargaining solutions induce different levels of arming and demonstrate how different bargaining solutions can be Pareto-ranked under some conditions.

Thus, given guns, under Limited Settlement the two agents divide the contested land T_0 according to γ and then go their separate ways. To endogenise the division rule with the use of the Nash bargaining solution, we must choose γ to maximise the (Nash) product $[V^1(\gamma, G_1) - U^1][V^2(\gamma, G_2) - U^2]$ with $U^i \equiv U^i(G_1, G_2)$ and $V^i(\gamma, G_i)$ being defined in (1) and (3), respectively. The first-order condition for an interior solution to this problem is

$$\frac{F(T_1 + \gamma T_0, R_1 - G_1) - U^1(G_1, G_2)}{F[T_2 + (1 - \gamma)T_0, R_2 - G_2] - U^2(G_1, G_2)} = \frac{F_T(T_1 + \gamma T_0, R_1 - G_1)}{F_T[T_2 + (1 - \gamma)T_0, R_2 - G_2]} \quad (4)$$

which defines $\gamma(G_1, G_2)$ implicitly as a function of guns. Substituting this share function back into (3) readily implies that we can rewrite the payoff functions under Limited Settlement as $V^i(G_1, G_2)$ for $i = 1,2$.

Turning to the Exchange regime, *ex post* Pareto optimality, coupled with the fact that the agents face identical homogeneous production functions, requires the following: for given guns, the remaining factor inputs should be combined in identical proportions so that the agents' individual land/labour ratios are equal to the aggregate land/labour ratio, T/L, where $T \equiv T_0 + T_1 + T_2$ and $L \equiv L_1 + L_2$ $(= R_1 - G_1 + R_2 - G_2)$. Because of constant returns to scale in production, this property is equivalent to the requirement that the agents pool their factor inputs to produce the total output $F(T, L)$, and then divide this output between them in a payoff-improving manner with, say, agent 1 receiving a share $\lambda \in [0, 1]$ and agent 2 receiving the remaining fraction $1 - \lambda$.[9] This implies that the agents' payoff functions can be written as

$$W^1(\lambda, G_1, G_2) = \lambda F(T, R_1 - G_1 + R_2 - G_2) \quad (5a)$$

$$W^2(\lambda, G_1, G_2) = (1 - \lambda)F(T, R_1 - G_1 + R_2 - G_2) \quad (5b)$$

for a given share λ. As earlier, we suppose λ is determined from the agents' maximisation of the (Nash) bargaining product $[W^1(\lambda, G_1, G_2) - U^1]$ $[W^2(\lambda, G_1, G_2) - U^2]$. The solution to this problem is

$$\lambda(G_1, G_2) = \frac{1}{2}\left[1 + \frac{U^1(G_1, G_2) - U^2(G_1, G_2)}{F(T, R_1 - G_1 + R_2 - G_2)}\right]. \quad (6)$$

Equation (6) indicates that under Exchange the agent with the larger disagreement payoff receives more than one-half of the total output. And, if the agents' payoffs under conflict do not differ, each agent receives one-half of the total payoff. By the just-described dependence of $\lambda(G_1, G_2)$ on guns, we can rewrite the payoff functions under Exchange in (5) in reduced form as $W^i(G_1, G_2)$ for $i = 1,2$.

In considering the agents' payoff functions under Limited Settlement in (3) and under Exchange in (5) it is useful to note the following: under Limited Settlement the contest is only over the disputed land T_0. In contrast, under Exchange the contest can be thought of as extending over the whole output. This difference holds the key to understanding our main findings in the following section.

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[9] Alternatively, the agents could divide land and then distribute the services of their labour so that the factor inputs under their individual control combine in the proportions just described.

2.2. *Comparing Limited Settlement and Exchange*

We first examine the case of two identical parties – that is, the one in which both agents own identical quantities of secure labour (ie, $R_1 = R_2$) and land endowments (ie, $T_1 = T_2$). Under these circumstances (i) there will exist a symmetric equilibrium for each regime, and (ii) *ex post* there will be no actual exchange in the Exchange regime (and therefore no *ex post* gains from exchange) because the agents are identical.[10] As we shall see, though, Limited Settlement and Exchange provide different incentives for arming.

We examine interior equilibria in which both agents choose positive quantities of guns. Note that if both agents were to choose a zero quantity of guns, we would be back in the neoclassical world in which there is perfect security of property.[11] The proof of the following proposition is in the Appendix.

PROPOSITION 1. *Suppose the sharing rules $\gamma(\cdot)$ and $\lambda(\cdot)$ under the regimes of Limited Settlement and Exchange, respectively, are both determined by the Nash bargaining solution, the two agents have identical secure resource endowments (ie, $R_1 = R_2$ and $T_1 = T_2$), and consider any combination of symmetric interior equilibria under the two regimes. Then, every agent $i(= 1,2)$ will*

(i) *produce a smaller quantity of guns under Limited Settlement than under Exchange;*
(ii) *have a larger payoff under Limited Settlement than under Exchange.*

What explains the less intense incentives to arm and, therefore, since there are no *ex post* gains from exchange, the dominance of Limited Settlement over Exchange? As mentioned earlier, the effective size of the 'pie' that becomes negotiable under Exchange is the whole surplus. In contrast, under Limited Settlement only the contested land is negotiable, and therefore the bargaining set is relatively smaller. Under these conditions each agent's perceived net benefit from allocating labour into arms is relatively higher under Exchange. The end result is relatively higher arming, fewer resources left for productive use and therefore relatively lower welfare under Exchange.

Fig. 1 helps visualise this finding. By construction, point E depicts a symmetric configuration in which $G_1 = G_2$. A small increase in G_1 shifts both the threat point A and the location of the payoff frontier. However, agent 1's net marginal benefit under Exchange is larger than the corresponding net benefit under Limited Settlement because the payoff frontier C_1C_2 under the former regime dominates the payoff frontier B_1B_2 under the latter, as explained in Section 1. Alternatively, since the disagreement payoffs are affected identically under both regimes as G_1 rises, agent 1 benefits more at

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[10] In a supplementary Appendix, which is available from the authors upon request, we show existence of pure-strategy equilibria under Conflict, Limited Settlement, and Exchange under general conditions on the contest success function and the sharing rules.

[11] It can be shown that such equilibria will obtain if the size of the contested land is large enough, the technology of conflict is sufficiently effective, and the marginal productivity of land is high enough relative to that of labour. These conditions can be established using methods similar to those in Skaperdas (1992). The effectiveness of conflict is defined as the derivative of p with respect to an agent's own gun choice, evaluated at zero.

the margin when his payoff rises locally along $C_1 C_2$ (Exchange) than when it rises along $B_1 B_2$ (Limited Settlement).

By continuity, the Pareto dominance of Limited Settlement over Exchange established in Proposition 1 should prevail for sufficiently small differences in the two parties' secure factor endowments. The extent to which this relationship holds, however, and whether it will change cannot be assessed generally as in Proposition 1; specific functional forms and numerical methods are needed. Here, for brevity, we just present Fig. 2 to provide a flavour of what can be expected in the presence of asymmetries and only summarise our other findings. In Fig. 2 the production and contest success functions take the following forms: $F(T, L) = T^{\alpha} L^{1-\alpha}$, $0 < \alpha < 1$, and $p(G_1, G_2) = G_1/(G_1 + G_2)$. The aggregate supply of the secure resource R is fixed at 100 units and the entire quantity of land T is insecure (ie, $T_1 = T_2 = 0$).

V^i: Payoff under Limited Settlement

W^i: Payoff under Exchange

$i = 1,2$

$$R_1 + R_2 = 100$$
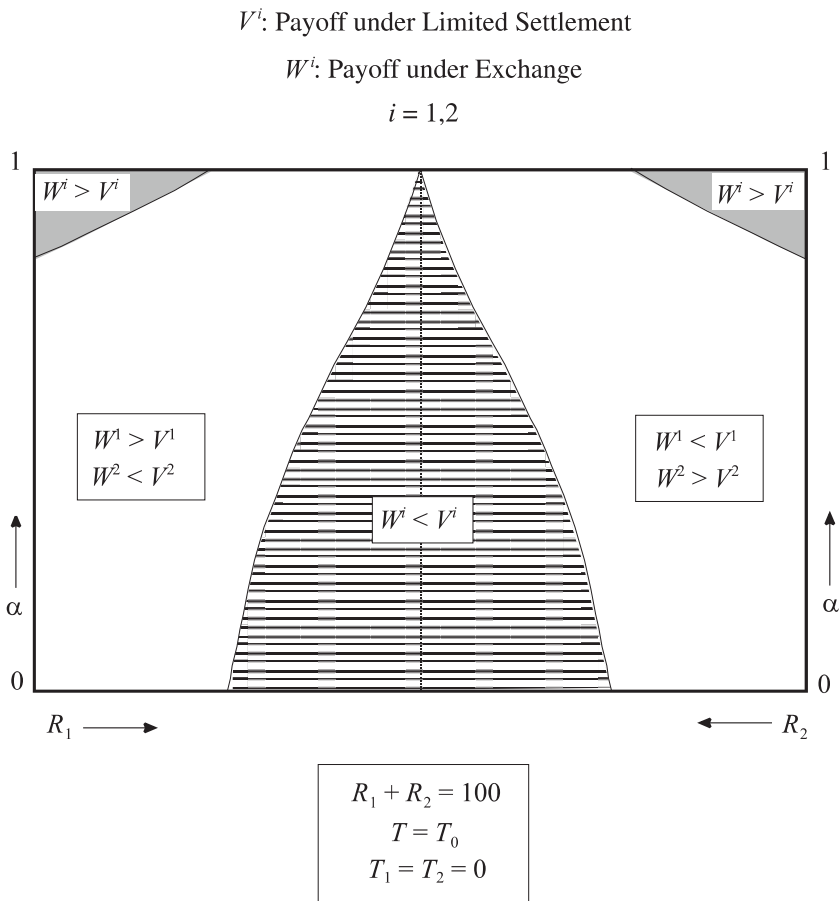$$T = T_0$$
$$T_1 = T_2 = 0$$

Fig. 2. *Different Resources*

Figure 2 shows how the equilibrium payoff rankings under the two regimes depend on the distribution of the aggregate labour endowment between the two agents and the technological parameter α. When the two parties are sufficiently similar in their initial endowments of labour (R), Limited Settlement is *ex ante* superior to Exchange for both agents. The intuition is similar to that of Proposition 1: The *ex post* gains from trade are too small relative to the costs of enforcement. Further, Fig. 2 also shows that when the two parties are *sufficiently different* in their initial labour endowments *and* parameter α is *sufficiently large*, Exchange is *ex ante* preferred by both parties. Here is one of the central clues in understanding this finding: when α is large, land is relatively more important in the production of the final good and this implies that the difference between what is contested under Limited Settlement (ie, land) and under Exchange (ie, the whole output) becomes smaller. In turn, this implies that the difference in the enforcement costs between the two regimes diminishes as α becomes larger. On the other hand, the more pronounced the difference in agents' initial labour endowments, the larger the (*ex post*) gains from trade. In short, then, when α is large and the initial distribution of labour ownership is sufficiently asymmetric, Exchange *ex ante* dominates Limited Settlement because the *ex post* gains from trade dominate the enforcement costs for both agents.

Overall, taking into account similar exercises to those underlying Fig. 2, Exchange is more likely to be the *ex ante* Pareto-dominant regime (i) the *more dissimilar* are the two parties in their relative endowments (the gains from trade are larger); (ii) the *more important* is the contested resource (and the less important is the labour input with a larger α) in the production of the final good, and (iii) the *smaller* is the overall degree of insecurity in the contested resource. Otherwise, either Limited Settlement dominates or one agent prefers it over Exchange. In the latter case, and since it takes two to tango (ie, for Exchange to arise), Limited Settlement would appear to be the more stable outcome.

3. Concluding Remarks

We have examined a simple model that allows for exchange in the presence of an insecure and contested resource. The limit of the model as property becomes perfectly secure is the familiar model of exchange that underpins the Edgeworth box. Just as the illustration of the gains from trade provided by the Edgeworth box is not specific to the model on which it is based, so is our analysis of insecurity and exchange. Enforcement costs in the presence of insecure resources might negate some or even all gains from trade; and the extent to which they might do this depends on the degree of insecurity and the economic environment considered. Importantly, as the exchange of goods reflects their factor content, it is not central for the results whether the traded commodities themselves or the resources used to produce these commodities are contested. That is, the free exchange of final goods whose endowments are secure but which have been produced with inputs that are

insecure can have the same effects as if the insecure inputs themselves were freely tradeable.

Given the possibility that exchange can be *ex ante* less efficient than more limited forms of settlement in economic environments with high insecurity, incentives might exist to have restrictions on exchange, not necessarily just on the contested inputs but also on final goods, thus substantiating the correlation between insecure property and exchange restrictions that we mentioned in the introduction. In Europe at the time of feudalism, for example, rampant insecurity in land, in other goods, and in life itself was accompanied by a limited transferability of land (see, eg, Anderson (1996) pp. 147–53) as well as numerous other restrictions that rendered feudal manors virtually autarkic. Later, during the time of mercantilism, the insecurity that existed at the international level was accompanied by the doctrine and practice of each state denying other states access to their markets for essentially security reasons. The relevance of enforcement costs in the exchange restrictions that have existed for all of human history and continue to exist in much of the world today could hardly be denied by those who have some knowledge of history and the institutions that govern the real economy. Since, however, there has been little, if any, formalisation of enforcement costs and especially its relationship to exchange, historical and empirical economic analyses of the connections have been hampered by the limited theoretical development.

Economists have been aware though of the relevance of insecurity and enforcement for economic activity. For instance, more than a century ago, Edgeworth made the following observation in his foundational *Mathematical Psychics*:

> The first principle of Economics is that every agent is actuated only by self-interest. The workings of this principle may be viewed under two aspects, according as the agent acts *without*, or *with*, the consent of others affected by his actions. In wide senses, the first species of action may be called *war*; the second, *contract*. (Edgeworth (1967) [1881], pp. 16–7; emphasis in the original)

Though Edgeworth's insights on *contract* revolutionised economic theory, he himself did not explore the economic implications of *war* and, perhaps more importantly, how the potential for *war* conditions the nature of *contract*. In attempting to examine the relationship between these two manifestations of self-interest in this article we have barely scratched the surface; nevertheless, along with the stimulus of other recent work we cite we hope more attention is being paid to this empirically important but neglected topic.

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Appendix

Proof of Proposition 1: Part (i): By symmetry, it is sufficient to consider only one agent, say agent 1. We must show that $G_1^S < G_1^E$ where superscript $S(E)$ identifies any symmetric equilibrium under the regime of Limited Settlement (Exchange). Differentiation of agent 1's payoff functions W^1 and V^1 under Exchange and Limited Settlement, respectively, with respect to G_1 yields

$$\frac{1}{W^1}\frac{\partial W^1}{\partial G_1} = \frac{\lambda_{G_1}}{\lambda} - \frac{F_L}{F} \tag{A.1a}$$

$$\frac{1}{V^1}\frac{\partial V^1}{\partial G_1} = \frac{\gamma T_0 F_T^1}{F^1}\frac{\gamma_{G_1}}{\gamma} - \frac{F_L^1}{F^1} \tag{A.1b}$$

where $F \equiv F(T, L)$ and $F^1 \equiv F(T_1 + \gamma T_0, L_1)$. (Recall that $T \equiv T_0 + T_1 + T_2$ and $L \equiv L_1 + L_2 = R_1 - G_1 + R_2 - G_2$.) To compare the agents' incentives to build guns under the two regimes, we must first find expressions for λ_{G_1}/λ and γ_{G_1}/γ.

Recall that the share function $\lambda(G_1, G_2)$ under Exchange equals $\text{argmax}_\lambda(W^1 - U^1)$ $(W^2 - U^2)$. Similarly, the share function $\gamma(G_1, G_2)$ under Limited Settlement equals $\text{argmax}_\gamma(V^1 - U^1)(V^2 - U^2)$. The FOCs for interior solutions to these problems (see (4) and (6)), can be rewritten as

$$W^1 - U^1 = W^2 - U^2 \quad \Rightarrow \quad \lambda = \frac{1}{2}\left(1 + \frac{U^1 - U^2}{F}\right) \tag{A.2a}$$

$$\Phi(\gamma, G_1, G_2) \equiv \frac{V^2 - U^2}{V^1 - U^1} = -\frac{\partial V^2/\partial \gamma}{\partial V^1/\partial \gamma} \equiv \Psi(\gamma, G_1, G_2). \tag{A.2b}$$

Differentiating $\lambda(G_1, G_2)$ in (A.2a) with respect to G_1 and utilising symmetry yields

$$\frac{\lambda_{G_1}}{\lambda} = \frac{U_{G_1}^1 - U_{G_1}^2}{2\lambda F} + \left(\frac{U^1 - U^2}{2\lambda F}\right)\left(\frac{F_L}{F}\right) = \frac{U_{G_1}^1 - U_{G_1}^2}{2F^1}. \tag{A.3a}$$

Notice that under conditions of symmetry (i) the expression in parenthesis on the right-hand side (RHS) of (A.3a) vanishes, and (ii) $\lambda F = F^1$. Similarly, differentiation of (A.2b) gives

$$\gamma_{G_1} = \frac{\Psi_\gamma}{\Psi_\gamma - \Phi_\gamma}\left(-\frac{\Psi_{G_1}}{\Psi_\gamma}\right) - \frac{\Phi_\gamma}{\Psi_\gamma - \Phi_\gamma}\left(-\frac{\Phi_{G_1}}{\Phi_\gamma}\right). \tag{A.3b}$$

Again, utilising symmetry, the definitions of the Φ and Ψ function in (A.2b), the payoff functions in (1) under conflict and in (5) under Exchange, and evaluating expressions at $G_1 = G_2$ yields

$$\Phi_{G_1} = \frac{U_{G_1}^1 - U_{G_1}^2 + F_L^1}{V^1 - U^1}, \ \Phi_\gamma = -\frac{2T_0 F_T^1}{V^1 - U^1} < 0 \quad \Rightarrow \quad -\frac{\Phi_{G_1}}{\Phi_\gamma} = \frac{U_{G_1}^1 - U_{G_1}^2 + F_L^1}{2T_0 F_T^1} \tag{A.4}$$

$$\Psi_{G_1} = \frac{F_{TL}^1}{F_T^1} > 0, \ \Psi_\gamma = -\frac{2T_0 F_{TT}^1}{F_T^1} > 0 \quad \Rightarrow \quad -\frac{\Psi_{G_1}}{\Psi_\gamma} = \frac{F_{TL}^1}{2T_0 F_{TT}^1} < 0. \tag{A.5}$$

From (A.3b) and the above it follows that γ_{G_1} is a weighted sum of the expressions in parenthesis in (A.3b). By the concavity of the production function in land, the first term in parenthesis in (A.3b) is negative, therefore $\gamma_{G_1} < -\Phi_{G_1}/\Phi_\gamma$. Utilising the expression for $-\Phi_{G_1}/\Phi_\gamma$ from (A.4) in this latter expression and manipulating it slightly leads to

$$\left(\frac{\gamma T_0 F_T^1}{F^1}\right)\left(\frac{\gamma_{G_1}}{\gamma}\right) < \frac{U_{G_1}^1 - U_{G_1}^2}{2F^1} + \frac{F_L^1}{2F^1}. \tag{A.6}$$

Subtracting F_L^1/F^1 from both sides of (A.6) and simplifying the RHS of the resulting expression yields

$$\left(\frac{\gamma T_0 F_T^1}{F^1}\right)\left(\frac{\gamma_{G_1}}{\gamma}\right) - \frac{F_L^1}{F^1} < \frac{U_{G_1}^1 - U_{G_1}^2}{2F^1} - \frac{F_L^1}{2F^1}. \tag{A.7}$$

By (A.1b), the LHS of (A.7) is equal to $(\partial V^1/\partial G_1)/V^1|_{G_1=G_2}$. Similarly, by (A.3$a$), the first expression on the RHS of (A.7) is equal to λ_{G_1}/λ. Consequently, we may rewrite (A.7) as

$$\frac{1}{V^1}\frac{\partial V^1}{\partial G_1}\bigg|_{G_1=G_2} < \frac{\lambda_{G_1}}{\lambda} - \frac{F_L}{F} + \left(\frac{F_L}{F} - \frac{F_L^1}{2F^1}\right)$$

By (A.1a), the first two expressions on the RHS of the above expression are equal to $(\partial W^1/\partial G_1)/W^1|_{G_1=G_2}$, so we can rewrite it as

$$\frac{1}{V^1}\frac{\partial V^1}{\partial G_1}\bigg|_{G_1=G_2} < \frac{1}{W^1}\frac{\partial W^1}{\partial G_1}\bigg|_{G_1=G_2} + \left(\frac{F_L}{F} - \frac{F_L^1}{2F^1}\right). \tag{A.8}$$

Now consider the expression in parenthesis in (A.8). By symmetry and the linear homogeneity of the production function this expression must vanish because $F = 2F^1$ and $F_L^1 = F_L$. Since this implies that

$$\frac{1}{V^1}\frac{\partial V^1}{\partial G_1}\bigg|_{G_1=G_2} < \frac{1}{W^1}\frac{\partial W^1}{\partial G_1}\bigg|_{G_1=G_2} \tag{A.9}$$

at every symmetric configuration of guns, it follows every agent's incentive to build guns is larger under the Exchange than under Limited Settlement. This completes the proof to part (i)

Part (ii): We must show that $V^1(G_1^S, G_1^S) < W^1(G_1^E, G_1^E)$. By symmetry, we have $V^1(G_1, G_1) = W^1(G_1, G_1) \; \forall \; G_1 \in [0, R_1]$, which states that given technology and endowments there are no *ex post* gains from trade because the agents are identical in every respect. Since these payoffs are decreasing in their argument and, as was just shown in part (i), both agents produce smaller quantities of guns under Limited Settlement than under Exchange, it must be the case that Limited Settlement dominates Exchange under conditions of symmetry.

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